RELATIONSHIP BETWEEN DECOMPOSITION LEVEL AND INDUCED SOLIDIFICATION OF PEAT BASED ON LABORATORY INVESTIGATION

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Special for:

Beloved husband
Mohd Zamani bin Ngali

Dearest daughters and sons
Zinniroh Lubna, Wafi Marina, Muhammad Yusuff Danish & Abdullah Rayyan

Family
Mom, siblings and in-laws

Dedicated Supervisor
Assoc. Prof. Dr. Chan Chee Ming

And

Supporting friends
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Love all of you

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ABSTRACT

Over 60 % of Pontian district is covered by peat. Peat is considered as a poor quality soil for construction due to the high moisture content and low bearing capacity. Solidification of peat is important in this area before any construction work could start thus, will increase the population rate in the district. The degree of decomposition affects the porosity of peat while the porosity is affected by both particle size and structure of the peat. The pores between the decomposed materials in peat can be filled and bound using ordinary portland cement (OPC) and coal ash (fly ash, FA and bottom ash, BA). Different decomposition levels of peat require different amounts of filler and binder to achieve the optimum strength. The peats are categorized as fabric for the less decomposed peat, hemic for the moderately decomposed and sapric for the mostly decomposed peat. The Pontian peat has high moisture content with fabric peat having 970 %, hemic peat, 417 % and sapric peat, 720 %. All peat was found acidic with pH 3-4.5 while the binders and filler are in alkaline state. The physico-chemical and mechanical properties of peat were identified according to British (BS 1377, 1990) and US (ASTM, 2000) standards. Chemical tests were adopted from previous researchers to identify the chemical properties. The mixtures of peat-binder-filler were subjected to the unconfined compressive strength (UCS) test, bender element (BE) test and the same chemical tests as applied for the original sample. The mix ratios examined were of four types being 100 % OPC, 50 % OPC 50 % BA, 50 % OPC 25 % BA 25 % FA and 25 % OPC 50 % BA 25 % FA. Two water-binder ratios were used, i.e. 1 and 3. Curing periods of 7, 14, 28 and 56 days were applied for all samples. The moisture content of the peat was controlled at 300 % before mixing. The scanning electron microscope (SEM) result shows that over time, the peat was filled with calcium silicate hydrate (CSH) and calcium aluminate hydrate (CAH) which were products of cement hydration. The strength gain for fabric peat is 157 kPa, while hemic peat, 737 kPa and sapric peat, 121 kPa. It is concluded that regardless the peat decomposition level, the optimum for a peat-binder-filler mixture to get the significant strength, should consist of i) 23 - 34 % of particles, being combination of peat fiber and BA with size ranging from 2 mm to 0.15 mm, ii) OPC with equal amount of dry mass of the peat and iii) 25 % of FA by the total mass of binder. This combination was found to be effective for the peat-binder-filler mixture.

Keywords: *Peat decomposition level, bottom ash, fly ash, OPC, solidification.*

ABSTRAK

Lebih 60 % daripada daerah Pontian adalah terdiri dari tanah gambut. Tanah gambut lazimnya dikenali sebagai tanah yang tidak berkualiti bagi sebarang kerja-kerja binaan disebabkan oleh kandungan lembapan yang sangat tinggi dan kapasiti galas yang rendah. Pemejalan tanah gambut di kawasan ini adalah penting sebelum sebarang kerja-kerja pembinaan boleh dimulakan dimana ia akan meningkatkan tahap populasi di daerah ini. Tahap penguraian tanah gambut memberi kesan kepada tahap keliangan tanah manakala tahap keliangan pula dipengaruhi oleh saiz zarah dan struktur tanah gambut tersebut. Liang-liang diantara bahan yang telah terurai boleh dipenuhi dan diikat menggunakan semen portland biasa (OPC) dan abu arang batu (abu atas, FA dan abu bawah, BA). Tahap penguraian tanah gambut yang berbeza memerlukan jumlah pengisi dan pengikat yang berbeza bagi mencapai kekuatan yang optimum. Tanah gambut dikategorikan sebagai gambut fabrik bagi yang kurang terurai, gambut hemik bagi separa terurai dan gambut saprik bagi yang paling terurai. Tanah gambut Pontian mempunyai kadar kelembapan yang tinggi dengan gambut fabrik 970 %, gambut hemic, 417 % dan gambut saprik, 720 %. Semua jenis gambut didapati berasid dengan pH 3-4.5 sementara pengikat dan pengisi adalah dalam tahap alkali. Sifat fizik-kimia dan mekanikal tanah gambut dikenalpasti berdasarkan standard British (BS 1377, 1990) dan US (ASTM, 2000). Ujian kimia pula diadaptasi dari kajian-kajian terdahulu bagi mengenalpasti sifat-sifat kimia bahan. Campuran tanah gambut-pengikat-pengisi adalah tertakluk kepada ujian kekuatan mampatan tak terkurung (UCS), ujian unsur terbengkok (BE) dan ujian kimia yang sama seperti yang telah dilakukan keatas sampel asal. Terdapat empat nisbah campuran yang diuji iaitu 100 % OPC, 50 % OPC 50 % BA, 50 % OPC 25 % BA 25 % FA dan 25 % OPC 50 % BA 25 % FA. Dua jenis nisbah air-pengikat digunakan iaitu 1 dan 3. Tempoh bertenang 7, 14, 28 dan 56 hari telah diaplikasi pada semua sampel. Kandungan lembapan tanah gambut telah dikawal pada 300 % sebelum pencampuran dibuat. Keputusan dari imbasan mikroskop elektron (SEM) menunjukkan dengan bertambahnya masa, tanah gambut telah diisi dengan calcium silicate hydrate (CSH) dan calcium aluminate hydrate (CAH), dimana ia adalah hasil dari proses penghidratan simen. Kekuatan yang telah dicapai oleh gambut fabrik ialah 157 kPa, gambaut hemik, 737 kPa dan gambut saprik, 121 kPa. Kesimpulannya, bagi sebarang jenis tanah gambut, campuran optimum bagi sebatian gambut-pengikat-pengisi mendapatkan kekuatan yang signifikan mestilah terdiri daripada, i) 23 - 34 % partikel, kombinasi fiber dari tanah gambut dan abu bawah dengan saiz julat dari 2 mm ke 0.15 mm, ii) kuantiti OPC yang sama banyak dengan jisim tanah gambut kering, dan iii) 25 % FA berasaskan jisim keseluruhan sebatian. Kombinasi campuran ini didapati efektif bagi sebatian gambut-pengikat-pengisi.

Kata kunci*: tahap penguraian tanah gambut, abu atas, abu bawah, OPC, pemejalan*

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LIST OF SYMBOLS AND ABBREVIATION

AASHTO	American Association of State Highway and Transportation Officials
Al_2O_3	aluminium oxide
ASTM	American Society for testing and Materials International Standard
BA	Bottom ash
BE	Bender Element
BS	Bristish Standard
C	Cement
C_2S	Dicalcium silicate
C_2SH_x, $C_3S_2H_x$	Hydrated calcium silicates
C_3A	Tricalcium aluminate
C_3S	Tricalcium silicate
C_4AF	Tetracalcium aliminofferrite
CaO	calcium oxide
CH	calcium hydroxide
CILAS	Particle Size Analyzer
CSH	calcium silicate hydrate
Cl	Chlorine
C_u	Undrained shear strength
C_v	Coefficient of consolidation
D	Diameter
e	Void ratio
E_o	Initial Tangent Modulus
E_p	secant modulus at peak stress
E_{50}	50 % of peak stress
EC	Electrical conductivity

e.g.	For example
EDS	Energy-dispersive X-ray Spectroscopy
ET	ettringite
et al	and other people
etc	and others
F	Fibric peat
FA	Fly ash
Fe_2O_3	feric oxide
FESEM	Field Emission Scanning Electron Microscope
FTIR	Fourier Transform Infrared Spectroscopy
g	Gram
G_{max}	maximum shear modulus
G_s	Specific gravity
GWT	Ground water table
H	Hemic peat
i.e.	In other words
i.e.	that is
kg	Kilogram
kN	Kilo Newton
kPa	Kilo Pascal
L	Length
LL	Liquid limit
LOI	Loss on ignition
MARDI	Malaysia Agricultural Research and Development Institute
Mg	Mega gram (1000 kg)
mm	Milimeter
MSCS	Malaysian Soil Classification System
N	Ignition loss
^oC	degree celcius
OC	Organic content
OPC	Ordinary Portland cement
q_u	Unconfined compressive strength
RECESS	Research Centre for Soft Soils
S	Sapric peat

SEM	Scanning electron microscopy
SiO_2	silica dioxide
SO_3	sulfur dioxide
TGA	Thermogravimetric Analysis
UCS	Unconfined compressive strength
USCS	unified soil classification systems
USDA	United States Department of Agriculture
UTHM	Universiti Tun Hussein Onn Malaysia
v_s	shear wave velocity
v_p	compression wave velocity
W (%)	percent moisture content
w	Water content
w/c	Water-cement ratio
w_n	Natural water content
W_S	Weight of dry soil
XRF	X – Ray fluorescence
ZnO	zinc oxide

CHAPTER 1

INTRODUCTION

1.1 Overview

Over 60 % of Pontian district is covered with peat as shown in **Figure 1.1**. **Figure 1.2** shows that Pontian has least population compared with other towns in Johor. It reflects that peat area is not a preferred inhabitants place due to limitation of the road network and infrastructure. Engineers are reluctant to construct on peat due to challenging accessibility to the sites and other problems related to the unique characteristics of peat. Report from National Audit Department (2011) stated that most projects that have been delayed and reconstructed were due to peat settlement. Hence, it is important to have peat treatment in this area to catalyze the population rate and to avoid unbalanced district population over time i,e, some cities to be more congested compared to the others.

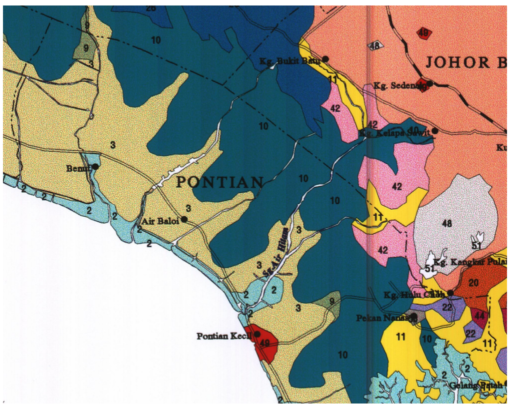


Figure 1.1 Pontian district (Jabatan Pertanian Pontian, 2012)

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter describes the type of peat soil, binder and filler with its properties. The correlation between all these substances is critically discussed here.

2.2 Peat soil

2.2.1 Definition and review

Peat is generally referred as cumulative of decomposed plant material but it actually has various definitions, depending on the scope of usage. The standard definitions are as given in **Table 2.1**:

Table 2.1 General definitions of peat

Purpose of application	Definition	Reference
Geotechnical engineering	Peat = Organic content > 75 % Organic soils, clay or sand = organic content < 75 %	*ASTM D4427 – 92
Agriculture	Peat = Organic content > 20 %.	**USDA (Soil Taxonomy)
Soil science	Peat = Organic content > 35 %	**USDA (Soil Taxonomy)

*USDA = *United States Department of Agriculture*
ASTM = *American Society for Testing and Materials*

Based on the global chart of total peat deposit around the world, Malaysia is the 9th country with the highest total area of peat soil (**Figure 2.1**). The total area of peat soil in Malaysia is about 2.6 million hectares (26,000 km^2), of which 13 % are in Malaysian Peninsular, over 80 % in Sarawak and about 5 % in Sabah as shown in **Figure 2.2** (Leete, 2006).

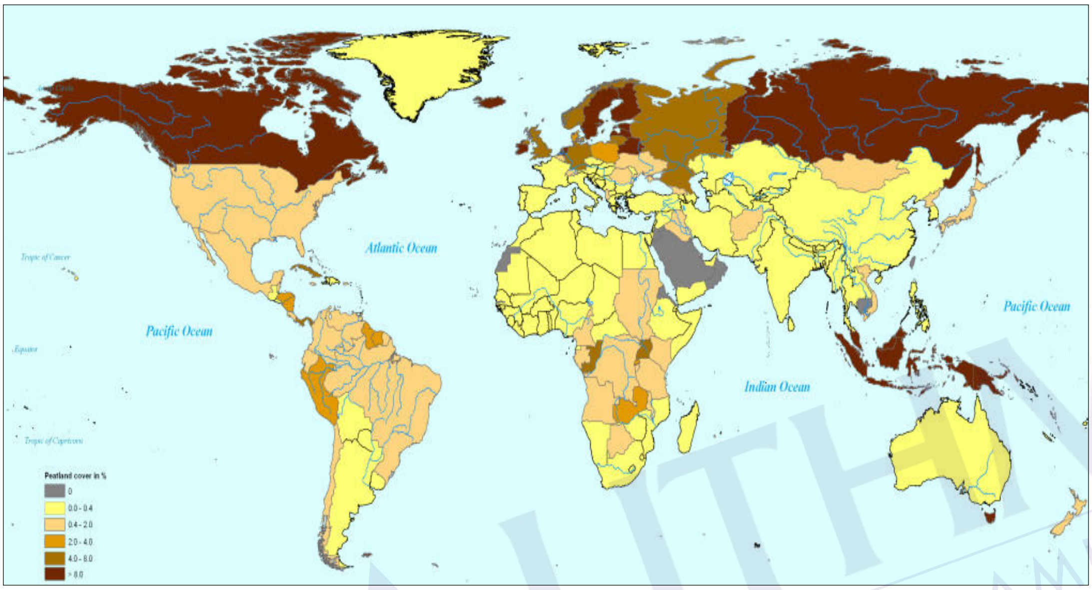


Figure 2.1 Peat distributions in the world (source: http://www.wetlands.org)

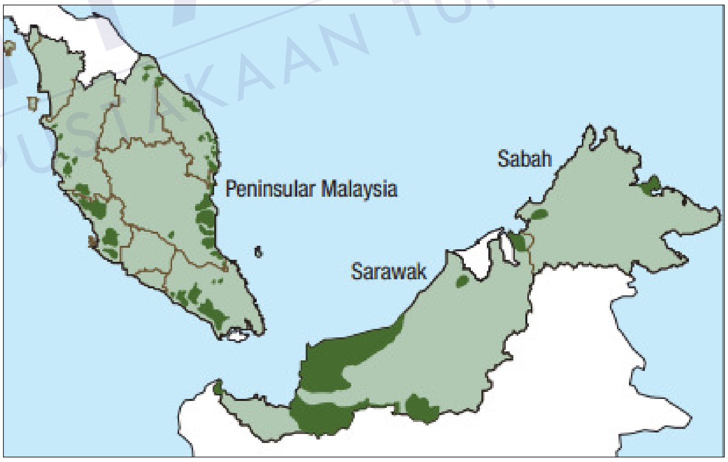


Figure 2.2 Distribution of peat swamp in Malaysia (Leete, 2006)

Technically, any material that contains carbon is called 'organic'. An organic soil is one that contains a significant amount of organic material recently derived from plant remains. The term peat refers to highly organic soils derived primarily from plant remains. It normally has a dark brown to black colour, a spongy consistency, and an organic odor. Plant fibers are sometimes visible but in the advanced stages of decomposition, they may not be evident. Peat is an organic soil with organic content of more than 75 % as defined by ASTM D4427 (**Table 2.1**).

2.2.2 Decomposition level of peat

There are several types of peat classification system for example, United State Department of Agriculture (USDA) (**Table 2.2**) and Van Post scale (**Table 2.3**). Both systems are comparable as depicted in **Table 2.2**. According to Van Post scale, peat classification is determined based on the appearance of soil water that is extruded when the soil is squeezed by hand. Degree of decomposition (humification) is expressed in terms of a ten-class scale on which higher numbers indicate stronger peat decomposition. The peat classification according to the USDA classification system will be used throughout this thesis.

Table 2.2 USDA classification of peat

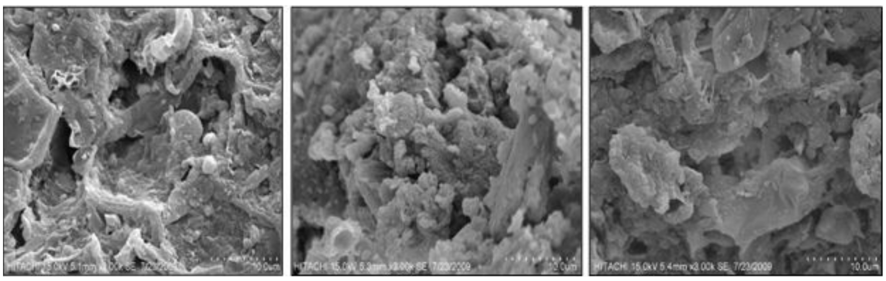
Type of peat	**Fiber content**	**Von Post Scale**
Fibric peat	Over 66 %	H4 or less
Hemic peat	33 - 66 %	H5- H6
Sapric peat	Less than 33 %	H7 and above

The degree of decomposition varies between peat mosses since some plants or some parts of the plants are more resistant than others. Also, the degree of decomposition of peat depends on combination of conditions, such as the chemistry of the water supply, the temperature of the region, aeration and the biochemical stability of the peatforming plant (Huat *et al.*, 2011). These variations make peat possesses wider range of physical properties such as colour, texture, density, specific gravity and water content.

Boelter (1968) reported that the physical properties of peat are highly affected by the porosity and the distribution of the pore size. Both parameters are related to grain size distribution. The degree of decomposition affects the porosity of peat and the porosity is affected by both the particle size and structure of peat. With an increase in the decomposition, the particle size of organic matters decreases (Boelter, 1968). Qualititatively, Scanning Electron Micrograph (SEM) is commonly used to observe this physical variation of peat. The arrangement of particles seen to be relatively loose in fibrous peat compared to the more decomposed peat, for example, sapric as seen in **Figure 2.3**. The morphology, structure of peat is shown in **Figure 2.4**. The remnants of logs and woody plant can be seen clearly in fibrous peat but almost absent in sapric peat.

Table 2.3 Degree of Humification of Peat (Von Post and Granlund 1926)

Degree of humification	Description
H1	Completely undecomposed peat which releases almost clear water. Plant remains easily identifiable. No amorphous material present.
H2	Almost completely undecomposed peat which releases clear or yellowish water. Plant remains still easily identifiable. No amorphous material present.
H3	Very slightly decomposed peat which releases muddy brown water but for which no peat passes between the fingers. Plant remains still identifiable and no amorphous material present.
H4	Slightly decomposed peat which, when squeezed, releases very muddy dark water. No peat is passed between the fingers but the plant remains are slightly pasty and have lost some of their identifiable features.
H5	Moderately decomposed peat which, when squeezed, releases very "muddy" water with a very small amount of amorphous granular peat escaping between the fingers. The structure of the plant remains is quite indistinct although it is still possible to recognize certain features. The residue is very pasty.
H6	Moderately decomposed peat which a very indistinct plant structure. When squeezed, about one-third of the peat escapes between the fingers. The structure more distinctly than before squeezing.
H7	Highly decomposed peat. Contains a lot of amorphous material with very faintly recognizable plant structure. When squeezed, about one – half of the peat escapes between the fingers. The water, if any is released, is very dark and almost pasty.
H8	Very highly decomposed peat with large quantity of amorphous material with very indistinct plant structure. When squeezed, about two thirds of the peat escapes between the fingers. A small quantity of pasty water may be released. The plant material remaining in the hand consists of residues such as roots and fibers that resist decomposition.
H9	Practically fully decomposed peat in which there is hardly any recognizable plant structure. When squeezed it is fairly uniform paste.
H10	Completely decomposed peat with no discernible plant structure. When squeezed, all the wet peat escapes between the fingers.



(a) (b) (c)

Figure 2.3 SEM images of peats: (a) fibrous, (b) sapric and (c) hemic (Huat *et al.*, 2011)

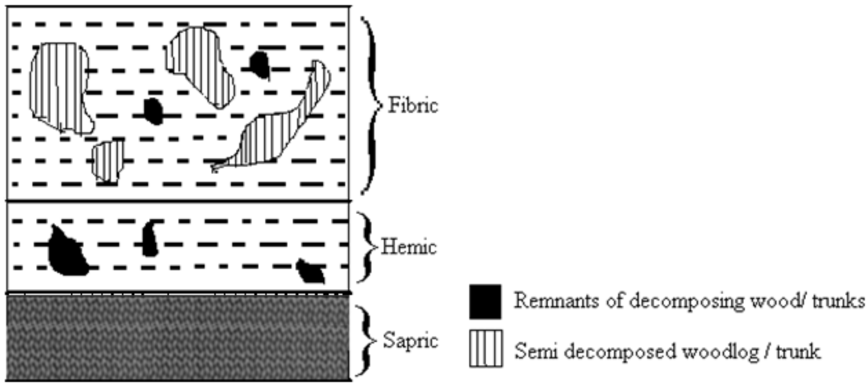


Figure 2.4 Profile morphology of drained organic soil (Mutalib *et al.*, 1992)

According to Hartford (1993), bulk density of organic soils or peat tends to increase with decomposition. Slightly decomposed organic soils (fibric peat) have larger pore spaces and higher rates of saturated water movement compared to well-decomposed sapric peat which may have hydraulic conductivity rates lower than clay soils (Robert, 1996).

Among three types of peat, namely: fibric, hemic and sapric, fibric or fibrous peat generally has very high natural water content due to its natural water-holding capacity. Soil fabric, characterized by organic coarse particles, holds a considerable amount of water because the course particles are generally very loose, and the organic particle itself is hollow and largely full of water. Previous researches have indicated that high water content of fibrous peat results in high buoyancy and high pore volume leading to low bulk density and low bearing capacity (Huat, 2004; Islam, 2009).

Table 2.4 lists the physical and chemical properties of peat. The comparison shows that the same type of peat may have a variety of natural water content, bulk density, specific gravity and acidity. Thus, the mentioned parameters cannot be used in determining the peat decomposition level. The higher moisture content of peat, normally reflect the ability of the fiber to retain water. Peat generally is acidic but, the level of acidity is influenced by the climate, the microbial activity in that specific location and type of plants that involved in peat accumulation. According to Mal and Maksimenok (1974), the formation of humic acid in peat is depending on the type of plant and temperature. Higher temperature increases the rate of formation of humic acid. The deeper the peat layer, the less temperature recorded thus resulting to humic acid production is stop or minimum. This causes the quantity of humic acid remain as the decomposing process continue.

Table 2.4 Physical and chemical properties of peat

Peat type	Natural water Content (w,%)	Bulk density (Mg/m^3)	Specific gravity (Gs)	Acidity (pH)	Reference
Fabric	1168	-	1.44	5.3	O'Kelly and Pichan (2013)
Peat	500 - 800	1.03	-	-	H. Hayashi *et al.* (2012)
Fabric	598.5		1.21	3.75	Kolay *et al.*(2011)
Fibric	605-1290	0.87-1.04	1.41-1.7	-	Moayedi *et al.* (2011)
Fibric	850	0.95-1.03	1.1-1.8	-	Asadi *et al*., (2009, 2010)
Fabric	700-850	1.59	1.343	4.6	Deboucha and Hashim (2009)
Fabric	668	-	1.4	3.51	Wong *et al.* (2008)
Fabric	510-850	-	1.53-1.65	-	Mesri and Ajlouni (2007)
	1000-1340		1.5-1.64		
Hemic	230-500	-	1.48-1.80	-	Zainorabidin and Ismail (2003)
Fabric and hemic	1090-1210	-	-	-	Jelisic and Leppänen (2000)
Fibric (Middleton)	510-850	0.99-1.1	1.47-1.64	4.2	Ajlouni (2000)
Fibric (James Bay)	1000-1340	0.85-1.02	1.37-1.55	5.3	
Peat (Netherlands)	669	0.97	1.52	-	Termatt and Topolnicki (1994)
Fibric	700-800	~1.00	-	-	Hansbo (1991)
Peat	630-1200	-	1.58-1.71	-	Nakayama *et al.* (1990)
Peat	400-1100	0.99-1.1	1.47	4.2	Yamaguchi 1990
Peat	419	1	1.61	-	Jones et al. (1986)
Peat	125-375	0	1.55-1.63	5-7	Yamaguchi *et al.* (1985)
Fibric	660-1590	-	1.53-1.68	-	Lefebvre *et al.* (1984)
Peat portage	600	0.96	1.72	7.3	Edil and Mochtar (1984)
Peat waupaca	460	0.96	1.68	6.2	
Fibric peat (Middleton)	510	0.91	1.41	7	
Fibric peat (Noblesville)	173-757	0.84	1.56	6.4	
Coarse Fibric	202-1159	1.05	1.5	4.17	Berry (1983)
Fine Fibric	660	1.05	1.58	6.9	NG and Eischen (1983)
Fine Fibric	418	1.05	1.73	6.9	
Hemic granular	336	1.05	1.72	7.3	
Fibric sedge	350	-	-	4.3	Levesque *et al.* (1980)
Fibric sphagnum	778	-	-	3.3	
Fibric peat	660-890	0.94-1.15	-	-	Olson and Mesri (1970)
Hemic peat	200-875	1.04-1.23	-	-	
Hemic to Fibric	850	-	1.5	-	Keene and Zawodniak (1968)
Hemic and Fibric	355-425	-	1.73	6.7	Adams (1965)
	500-1500	0.88-1.22	1.5-1.6	-	Lea and Browner (1963)

REFERENCES

Abd Rahman, J. and Chan, C.M. (2013). *Influence of Temperature on the Mass Losses of Tropical Peat at Different Decomposition Level.* Soft soil Engineering International Confrence 2013. Sarawak.

Abd Rahman, J. and Chan, C.M. (2014). *A preliminary study of the threshold limit for cementation of peat at different decomposition levels.* Zaytoonah University International Engineering Conference on Design and Innovation in Sustainability 2014 (ZEC Infrastructure 2014). Amman, Jordan.

Abd Rahman, J. and Chan, C.M. (2014). Effect of Additive to the Moisture Content at Different Decomposition Level of Peat. *Journal of Civil Engineering Research 2014*, 4(3A). 59-62.

Abdul Rahman, I. Memon, A. H., Nagapan, S. Bux, Q., Latif, A. I. and Abdul Azis, A. A. (2012). *Time and Cost Performance of Costruction Projects in Southern and Cenrtal Regions of Penisular Malaysia*. IEEE Colloquium on Humanities, Science & Engineering Research (CHUSER 2012), Malaysia. 52-57.

Adon, R., Bakar, I., Wijeyesekera, D. C., & Zainorabidin, A. (2013). Overview of the Sustainable Uses of Peat Soil in Malaysia with Some Relevant Geotechnical Assessments. *International Journal of Integrated Engineering*, *4*(3).

Ahnberg, H. (2006). *Consolidation stress effects on the strength of stabilised Swedish soils.* Ground Improvement, 10(1): 1-13. Digital Object Identifier (DOI): 10.1680/grim.2006.10.1.1.

Ahnberg, H. and Bengtsson, P.E. (2005) *Shear wave velocity and shear strength relation for binder-mixed soil – preliminary results from a laboratory study*. Vattenbyggaren, No. 4, pp. 46–51 (in Swedish).

Ahnberg, H. and Holmen, M. (2008). Assessment of stabilized soil strength with geophysical methods. *Ground Improvement*. Volume 164 Issue GI3. 109-116.

Akol, A. K.(2012). *Stabilization of peat soil using lime as a stabilizer.* Project dissertation .Civil Engineering Programme Universiti Teknologi PETRONAS.

Alawode, O. and Idowu, O. I. (2011). Effects of Water-Cement Ratios on the Compressive Strength and Workability of Concrete and Lateritic Concrete

Mixes. *The Pacific Journal of Science and Technology*. Volume 12. Number 2. 99-105.

Ali, F., Wong, L. S. and Hashim, R. (2010). Engineering properties of improved fibrous peat. *Scientific Research and Essay* Vol. 5 (2). 154-169.

Alwi, A. (2008). *Ground improvement of Malaysian peat soils using stabilized peat column techniques*. PhD thesis, University of Malaya, Kuala Lumpur, Malaysia.

American Society of Testing Materials (ASTM) (2000). Annual Book of ASTM Standards, Section four: Construction, vol. 04.08.

Andriesse, J.P. (1988). Nature and Management of Tropical Peat Soils. *FAO Soils Bulletin 59*, Rome.

Annual Book of ASTM Standards. (2000). *ASTM D 2974: Standard Test Method for Moisture, Ash, and Organic Matter of Peat and other Organic Soils.* USA: Philadelphia.

Annual Books of ASTM Standards. (1994). *ASTM C 618: Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolanic for Use as A Mineral Admixture in Portland Cement Concrete.* USA: Philadelphia.

Annual Books of ASTM Standards. (1996). *ASTM D 1997-91: Standard Test Method for Laboratory Determination of the Fiber Content of Peat Samples by Dry Mass*. USA: Philadelphia.

ASTM D2976-71. *Standard Test Method for pH of Peat Materials.* American Society for Testing and Materials. West Conshohocken,PA. 317-318.

ASTM D4427-07. (2007). *Standard Classification of Peat Samples by Laboratory Testing*. D 4427-92. ASTM International. Retrieved on March 23, 2013 from http://www.astm.org/Standards/D4427.htm.

Axelsson, K., Johansson, Sven-Erick. and Anderson, R. 2002. *Stabilization of organic soils by cement and pozzolanic reaction-feasability study*. Swedish Deep Stabilization Research Centre, Report 3, 1–51.

Barbosa, N. R. and Overstreet, C. (2010). *What Is Soil Electrical Conductivity?* LSU AgCenter Pub. 3185. 1-4.

Barefield, E. and Shakoor, A. (2006). *The effect of degree of saturation on the unconfined compressive strength of selected sandstones.* The Geological Society of London. IAEG2006 Paper number 606.

Barrière, J., Oth, A., Schenkluhn, R., Krein, *A.*(2013). *Joint Analysis of seismograms and hydroacoustic data for bedload transport monitoring in a small lowland river*. International workshop of acoustic and seismic monitoring of bedload and mass movements 2013, Swiss Federal Research Institute WSL, Birmensdorf, Switzerland.

Behzad, K and Huat, B.B. K. (2008). Peat soil stabilization using ordinary portland cement, polypropelene, fibers and air curing technique. *Electronic Journal of Geotechnical Engineering*, Vol. 13, Bund. J.

Bergado, D.T., Anderson, L.R., Miura, N.& Balasubramaniam, A.S. (1996*). Soft*

Bergner K. and Albano C. (1993). Thermal analysis of peat. Analitical Chemistry. 204-208.

Billong, N., Melo, U.C., Louvet, F., Njopwouo, D. (2009). *Properties of compressed lateritic soil stabilized with a burnt clay-lime binder: effect of mixture components. Construction and Building Materials* 23, 2457–2460.

Blissett, R.S. and Rowson, N.A. (2012). A review of the multi-component utilisation of coal fly ash. *Fuel* . Vol. 97.1–23.

Boelter, D.H. (1968). *Important physical properties of peat materials*. Proceedings of the Third International Peat Congress. Quebec,Canada. 150-156.

Book, A. A. (1985). Standard Classification of Peat Samples by Laboratory Testing (D4427-84). *ASTM, Section, 4*, 883-884.

Boulanger, R. W., Arulnathan, R., Harder Jr., L. F., Torres, R. A. and Driller, M. W. (1998). Dynamic properties of Sherman Island peat. *Journal of Geotech. Geoenvironment Engineering.*124. 12-20.

British Standard Institution, 1986. BS 8004: 1986. *Method of Test for Soils for Civil Engineering Purposes*.

British Standard Institution, 1990. BS 1377, 1-8: 1990. *Method of Test for Soils for Civil Engineering Purposes*.

Brouwer, P. N. (2010). *Theory of XRF*, 3rd edition, The Netherlands, PANalytical B.V.

Cancellieri, D., Leroy, C. V., Leoni, E., Simeoni, A., Kuzin, A. Y., Filkov, A. I. and Rein, G. (2012). Kinetic investigation on the smouldering combustion of boreal peat. *Fuel.* Vol. 93, 479–485.

Carey, F. and Giuliano R. (2001). Organic Chemistry, England, McGraw Hill, Sixth edition.

Cement and Its Impact on Concrete Performance. (2012). Portland Cement Association, USA.

Chan, C.M. (2006). *A Laboratory Investigation of Shear Wave Velocity in Stabilized Soft Soils*. PhD thesis, Department of Civil and Structural Engineering, University of Sheffield.

Chan, C.M. (2009). NeuSOIL: *Regenerating soft soils for engineering applications*. Engineering Seminar on Peat, Sibu, Sarawak.

Chan, C.M. (2012). *On the intepretation of shear wave velocity from bender element*

Chapman, S. J., Campbell, C. D., Fraser, A. R. and Puri, G. (2001). *FTIR spectroscopy of peat in and bordering Scots pine woodland: relationship with chemical and biological properties.* vol. 33. 1193–1200.

Chen, H. and Q. Wang, 2006. The behaviour of organic matter in the process of soft soil stabilization using cement. B. Eng. Geo. Environ., 65(4): 445-448.Digital Object Identifier (D OI): 10.1007/s10064-005-0030-1.

Chimenos, J. M., Segarra, M., Fernandez, M. A. and Espiell, F. (1999). Characterization of the bottom ash in municipal solid waste incinerator. *Journal of Hazardous Materials* A:64 1999 211–222.

Collins, R. (1988). *A Comparison between Coal Ash and Incinerator Ash.* Proceedings of the First International Conference on Municipal Solid Waste Combustor Ash Utilization, Philadelphia. 99 - 108.

Consoli, N. C., Zortéa, F. de Souza, M. and Festugato, L. (2011). Studies on the Dosage of Fiber-Reinforced Cemented Soils. *Journal of Materials in Civil Engineering* © ASCE . 1624-1632.

Consoli, N.C., G.V. Rotta and P.D.M. Prietto (2002). *Influence of curing under stress on the triaxial response of cemented soils*. Geotechnique, 52(5): 382-384.

Cwalina, B. (2008). Biodeterioration of concrete. *Architecture Civil Engineering Environment.* 133-140.

Deboucha, S. and Hashim, R. (2009). Durability and swelling of tropical stabilized peat soils. *Journal of Applied Sciences* 9 (13). 2480-2484.

Den Haan, E. J. (1997). *An overview of the mechanical behaviour of peats and organic soils and some appropriate construction techniques*. Conference on Recent Advances in Soft Soil Engineering, 5-7 March, Sarawak, Malaysia. By Ahnberg, H. and Holm, G. (2009). *Influence of laboratory procedures on* *properties of stabilized soil specimens*. In International Symposium on Deep Mixing and Admixture Stabilization, Okinawa 12-21 May.

Dehghanbanadaki, A., Ahmad, K. and Ali, N. (2013).Influence of natural fillers on shear strength of cement treated peat. *Gradevinar 65*. 633-640.

Dobry, R. and Vucetic, M. (1987). *State of the art report: Dynamic properties and response of soft clay deposits*. Proceeding, International Symposium on Geotechnics Engineering of Soft Soils, Mexico City, Vol. 2. 51–87.

Douglas, P.R., 2004. Properties of self-consolidating concrete containing type F fly ash. Thesis (MS). North western University. USA.

Dunlap, M. and Adaskaveg, J.E. (1997). *Introduction to the Scanning Electron Microscope, Theory, Practice, & Procedures*, Facility for Advanced Instrumentation, U. C. Davis.

El-Jazairi, B. & Illston, J.M. (1977). A Simultaneous Semi-Isothermal Method of Thermogravimetry and Derivative Thermogravimetry, and Its Application to Cement Plates. *Cement and Concrete Research,* Vol.7, 247-258.

El-Jazairi, B. & Illston, J.M. (1980). The Hydration of Cement Plate Using the SemiIsothermal Method of Thermogravimetry. *Cement and Concrete Research,* Vol.10, 361-366.

Erol, M., Küçükbayrak, S. and Ersoy-Meriçboyu, A. (2008). Characterization of sintered coal fly ashes. *Fuel*. Vol. 87. 1334–40.

EuroSoilStab. (2002). *Development of design and construction methods to stabilize soft organic soils (design guide soft soil stabilisation)*. European Comission, Industrial and Material Technologies programme (Brite-EuRam III), Brussels.

Ferrari, L., Kaufmann, J., Winnefeld, F. and Plank, J. (2011). Multi-method approach to study influence of superplasticizers on cement suspensions. *Cement and Concrete Research.* 41(10). 1058-1070.

Francioso O., Ciavatta C., Montecchio D., Tugnoli V., Sanchez-Cortes S., Gessa C.(2003). *Quantitative Estimation of Peat, Brown Coal and Lignite Humic Acids Using Chemical Parameters, 1H-NMR and DTA Analyses*. Bioresource Technology, N 88, 189-195.

Gofar, N. (2006). *Determination of coefficient of rate of horizontal consolidation of peat soil.* Laporan Projek Penyelidikan Fundamental Vot 75210. Faculty of Civil Engineering, Universiti Teknologi Malaysia.

Gofar, N. and Sutejo, Y. (2007). Long term compression behaviour of fibrous peat. *Malaysian Journal of Civil Engineering* 19(2) :104-116.

Greaves, G. N., Greer,A. L., Lakes, R. S. and Rouxel, T. (2011). Poisson's ratio and modern materials. *Nature Materials* 10, 823–837.

Ground Improvement in LowLand and Other Environments. American Society of Civil Engineers (ASCE) Press. 235-238.

Halstead, W.J. (1986). *Use of Fly Ash in Concrete.* Washington: Transportation Research Board, National Research Council.

Hamer, D.A. (2012), *Stabilization of peat by infiltration of reactants, feasibility study: infiltration of silica biopolymer suspension in peat*, Msc. Thesis University of Utrecht, Netherlands.

Harrison, A. M., Taylor, H. F. W., and Winter, N. B.(1985). Electron optical analyses of the phases in a portland cement clinker, with some observations on the calculation of quantitative phase composition. *Cement Concrete Research*.15:775.

Hartford, R. A. (1993). *Smoldering combustion limits in peat as influenced by moisture, mineral content, and organic bulk density* (Master's thesis, University of Montana).

Hashim, R. and Islam S. (2008). A Model Study to Determine Engineering Properties of Peat Soil and Effect on Strength after Stabilization. *European J. Scientific Res.*, 2, 205–215.

Hayashi, H., Yamazoe, N., Mitachi, T., Tanaka, H. and Nishimoto, S. (2012) Coefficient of earth pressure at rest for normally and overconsolidated peat ground in Hokkaido area. *Soils and Foundations* 52. The Japanese Geotechnical Society. 299–311.

Hebib, S. and Farell, E. R. (2003). Some experiences on the stabilisation of Irish peats: *Can. Geotech. Journal*. 40. 107-120.

Hingley, M. (1993). *Microscopic Life in Sphagnum*. Richmond Publishing, England.

Hiraide, A., Baba, K. and Azuma, H. (1996). *Quality assessment of stabilized soil by S-wave logging*. Proceedings of the 2nd International Conference on Ground Improvement Geosystems, Tokyo. AA Balkema, Rotterdam, the Netherlands. 603–606.

Hoo, L.S. (2013). *Solidification of Malaysian Dredged Soils: Strength Characteristics*. Bachelor Degree Thesis. Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia.

Horpibulsuk, S. (2012). Strength and Microstructure of Cement Stabilized Clay, Scanning Electron Microscopy. ISBN: 978-953-51-0092-8, InTech.

Horpibulsuk, S., Miura, N. and Nagaraj, T. S. (2005). Clay–Water/Cement Ratio Identity for Cement Admixed Soft Clays. *Journal of Geotechnical and Geoenvironmental Engneering* © ASCE. 187-192.

Horpibulsuk, S., Rachan, R., Chinkulkijniwat, A., Raksachon, Y. and Suddeepong, A., (2010). Analysis of strength development in cement-stabilized silty clay from microstructural considerations. *Construction and Building Materials* 24. 2011–2021.

Huat, B. B. K., Maail, S. and Mohamed, T. A. (2005). Effect of Chemical Admixtures on the Engineering Properties of Tropical Peat Soils. *American Journal of Applied Sciences*: Vol. 2 (7). 1113-1120.

Huat, B.B.K. (2004). *Organic and peat soil engineering*. Serdang, University Putra Malaysia Press.

Huat, B.B.K., Kazemian, S., Prasad, A. and Barghchi, M. (2011). State of an art review of peat: General perspective. *International Journal of the Physical Sciences Vol. 6(8)*, 1988-1996.

Hunter, P.J., Petch, G.M. and Calvo-Bado, L.A. (2006). Differences in microbial activity and microbial populations of peat associated with suppression of damping-off disease caused by Pythium sylvaticum. *Applied and Environmental Microbiology* 72(10). 6452–6460.

Islam, M. S. and Hashim, R. (2010). Behaviour of stabilised peat: A field . study. *Scientific Research and Essays* Vol. 5(17), 2366-2374.

Islam, M.D.I. and Hashim, R. (2008). Stabilization of Peat by Deep Mixing Method: A critical Review of the state of Practice. *Electronic J. of Geotechn. Eng.,* 13, Bund H.

Ismail, N., Nonaka, T., Noda, S.and Mori, T. (1993). Effect of carbonation on microbial corrosion of concretes. *Journal of Construction Man. and Engineering.* 133-138.

J. Cohen, (1988). *Statistical power analysis for the behavioral sciences*, 2nd ed.

Jackson, N. and Dhir, R.K. (1996). *Civil Engineering Materials 5th edition.* McMillan Publisher.

Janz, M. and Johansson, S. (2002). *The function of different binding agents in deep stabilization.* Report 9, Swedish Deep Stabilization Research Center, Linköping, Sweden. 1-47.

Jolicoeur, C. and Simard, M. A. (1998). Chemical Admixture-Cement Interactions: Phenomenology and Physico-chemical Concepts. Cement and Concrete Composires. Vol. 20. 87-101.

Kahn, Z., Majid, A., Cascante, G., Hutchinson, D.J. and Pezeshkpour, P. (2006). Characterization of a cemented sand with the pulsevelocity method. *Canadian Geotechnical Journal* 43(3): 294– 309.

Kalantari, B. (2010). *Stabilization of tropical fibrous peat using ordinary portland cement and additives*. PHD thesis. Universiti Putra Malaysia.

Kalantari, B. and Prasad, A. (2011). *Precast Peat Columns Stabilized with Cement and Fibers to Reinforce Peat Deposits*. 5th SASTech, Khavaran Higher-education Institute, Mashhad, Iran. 1-16.

Kalantari, B. and Prasad, A. (2014). A study of the effect of various curing techniques on the strength of stabilized peat. *Transportation Geotechnics* 1. 119–128.

Kazemian, S., Huat, B. B. K., Prasad, A. and Barghchi, M. (2011a). A state of art review of peat: Geotechnical engineering perspective. *International Journal of the Physical Sciences*. Vol. 6(8). 1974-1981.

Kazemian, S., Huat, B.K., Prasad, A. and Barghchi, M. (2011b). Effect of peat media on stabilization of peat by traditional binders, *International Journal of the Physical Sciences* Vol. 6(3), pp 476-481.

Kevan, D.S. (1993). *Fly Ash for Soil Improvement.* New York: American Society of Civil Engineers.

Kido, Y., Nishimoto, S., Hayashi, H. and Hashimoto, H. (2009). *Effects of curing temperatures on the strength of cement-treated peat.* Proceedings of International Symposium on Deep Mixing and Admixture Stabilization (Kitazume M and Terashi M (eds)), Okinawa.

Kido, Y., Nishimoto, S., Hayashi, H. and Hashimoto, H. (2009). *Effects of curing temperatures on the strength of cement-treated peat.* International Symposium on Deep Mixing and Admixture Stabilization, OKINAWA 2009.

Kolay, P.K, Sii, H. Y. and Taib, S.N.L.(2011).Tropical Peat Soil Stabilization using Class F Pond Ash from Coal Fired Power Plant *International Journal of Civil and Environmental Engineering* 3:2. 79-83.

Kosmatka, S. and Farny, J. (1997). *Concrete Technology Today*. Illinois ,USA. Portland Cement Association.

Krumins, J., Klavins, M., Seglins, V. and Kaup, E. (2012). Comparative Study of Peat Composition FT-IR Spectroscopy. *Material Science and Applied Chemistry.*106-114.

Laporan Ketua Audit Negara, Aktiviti Jabatan/Agensi Dan Pengurusan Syarikat Kerajaan Negeri Johor Tahun 2011, Jabatan Audit Negara, Malaysia.

Larkin, P. J. (2011). *IR and Raman: Principles and Spectral Interpretation*. Waltham, USA. Elsevier Inc.

Larsson, R., Holm, G., Ahnberg, H. and Bengtsson, P.E. (2005). *Shear wave velocity and shear strength relation for binder-mixed soil – preliminary results from a laboratory study*. No. 4. 46–51.

Lee, J. S. and Santamarina, J. C. (2005). Bender Elements: Performance and Signal Interpretation. *Journal of geotechnical and environmental engineering© ASCE*. 1063- 1070.

Leete, R. (2006). *Malaysia's Peat Swamp Forest Conservation and Sustainable Use. United Nations Development Programme Malaysia.* Ministry of Natural. Resources and Environment, Malaysia.

Leong, E. C. and Eriktius, D. T. (2013). Improvement of peaty soils with municipal solid waste fly ash. *Environmental Geotechnics* Volume 1 Issue EG4.200–209.

Leong, E.C., Yeo, S.H. and Rahardjo, H. (2005). Measuring shear wave velocity using bender elements. *Geotechnical Testing Journal* 28(5). 488–498.

Little, D. N. (1999). *Evaluation of structural properties of lime stabilized soils and aggregates. Summary of findings*, Volume I, National Lime Association, USA.

Liu, G., Vassilev, S. V., Gao, L., Zheng, L. and Peng, Z. (2005). Mineral and chemical composition and some trace element contents in coals and coal ashes from Huaibei coal field, China . *Energy Conversion and Management 46*. 2001–2009.

Ma, X. J. and Hua, J. M. (2005). Peat and peatlands. Encyclopaedia of Life Support System (EOLSS).

Maher, A., Douglass, W.S., Jafari, F. and Pecchioli, J. (2013). *The Processing and Beneficial Use of Fine-Grained Dredged Material: A Manual for Engineers.* RUTGERS. Centre of Advance Infrastructure and Transportation. New Jersey.

Mahlaba, J. S., Kearsley, E. P. and Kruger, R. A. (2011). Physical, chemical and mineralogical characterisation of hydraulically disposed fine coal ash from SASOL Synfuels. *Fuel*. Vol. 90. 2491–2500.

Mal, S.S. and Maksimenok,G.I. (1974). *An investigation of changes in the chemical composition of lowland peat in the process of self-heating. The formation of organic acids.* NASA Technical Report.

Maria Chrysochoou, A.M. (2013). Investigation of mineral dissolution rate and strength development in stabilized soils using quantitative X-ray Diffraction. ASCE. Journal of Materials in Civil Engineering.

Marto, A., Kassim, K. A., Makhtar, A.M., Wei, L.F. and Lim, Y.S. (2010).Engineering Characteristics of Tanjung Bin Coal Ash. *Engineering Journal of Geotechnical Engineering,* Vol. 15. 1117-1129.

Mattigod, S.V., Rai, D., Eary, L.E. & Ainsworth, C.C. (1990). *Geochemical Factors Controlling the Mobilization of Inorganic Constituents from Fossil Fuel Combustion Residues (I).* Review of the Major Elements. Journal of Environmental Quality, Vol.19:188.

Mattsson. H., Larsson, R., Holm, G., Dannewitz, N. and Eriksson, H. (2005). *Down-hole technique improves quality control on dry mix columns.* Proceedings of the International Conference on Deep Mixing, Stockholm. Swedish Deep Stabilization Research Centre, Linko¨ping, Sweden, vol. 1.2. 581–592.

McLaren, R.J. & DiGioia, A.M. (1987). *Geotechnical Practice for Waste Disposal: The Typical Engineering Properties of Fly Ash*. Geotechnical Special Publication.

Mehta, P.K. (1987). Natural pozzolans: Supplementary cementing materials in concrete. *CANMET Special Publication* 86. 1–33.

Melling, L. (1997). Adsorption of Cu & Zn in Tropical Peat Soil. *MAgrSc Thesis, University of Reading, UK.*

Mesri, G. and Ajlouni, M. (2007). Engineering Properties of Fibrous Peats. *Journal of Geotechnical and Geoenvironmental Engineering* 133:850-866.

Miller, C.A. & Linak, W.P. (2002). *Primary Particles Generated by the Combustion of Heavy Fuel Oil and Coal.* Review of Research Results from EPA's National Risk Manage. EPA-600/R-02-093. 31-35.

Mitchell, J. K., and Soga, K. (2005). *Fundamentals of soil behavior*, 3rd Ed., Wiley, New York.

Moayedi, H., Nazir, R., Kazemian, S. and Huat, B. K. (2014). Microstructure analysis of electrokinetically stabilized peat. *Measurement* 48. 187–194.

Mohamed, M., Padmanabhan, E., Mei, B. L. H. and Siong, W. B. (2002). *The Peat Soils of Sarawak*. Strapeat- status report, Universiti Malaysia Sarawak.

Mott, P. H. and Roland, C. M. (2012). *Limits to Poisson's ratio in isotropic materials – general result for arbitrary deformation.* Naval Research Laboratory, Washington DC. 1-15.

Mutalib, A. A., Lim, J. S., Wong, M. H. and Koonvai, L. (1992). *Characterization, distribution and utilization of peat in Malaysia*. In Aminudin, B. Y., (ed.). Proceeding of the International Symposium on Tropical Peatland, Serdang: MARDI. 7-16. By Mohamed, M., Padmanabhan, E., Mei, B. L. H. and Siong, W. B. (2002). *The Peat Soils of Sarawak*. Strapeat- status report, Universiti Malaysia Sarawak.

Newman, J. and Ban S.C. (2003). Advanced concrete technology: Constituent material. Great Britain: Biddles Ltd. 1/17 - 1/18.

Nontananandh, S., Thakon, Y., and Sanupong, B. (2005). Scanning electron microscopic investigation of cement stabilized soil. In *Proceeding of The 10th National Convention on Civil Engineering*. 23-26.

O'Kelly B.C. and Pichan S. P. (2014). Effect of decomposition on physical properties of fibrous peat. *Environmental Geotechnics*. 22–32.

O'Kelly, B.C. and Pichan, S. P. (2013). Effects of decomposition on the compressibility of fibrous peat — a review. *Geomechanics and Geoengineering: An International Journal* 8(4). 286–296.

Pichan, S. P. and O'Kelly, B.C. (2013). *Stimulated decomposition in peat for engineering applications*. Proceedings of the Institution of Civil Engineers, Ground Improvement 166(3). 168–176.

Porbaha, A., Ghaheri, F. and Puppala, A.J. (2005). *Soil cement properties from borehole geophysics correlated with laboratory tests.* Proceedings of the International Conference on Deep Mixing, Stockholm. Swedish Deep Stabilization Research Centre, Linko¨ping, Sweden, vol. 1. 605–611.

Pravettoni, R. (2009).The natural fix the role of ecosystems in climate mitigation, UNEP/GRID-Arendal.

Purmalis, O., Porsnovs, D. and Klavins, M. (2011). Differential Thermal Analysis of Peat and Peat Humic Acids. *Scientific Journal of Riga Technical University Material Science and Applied Chemistry*. 89-94.

Rao, S.M. and P. Shivananda (2005). Compressibility behaviour of lime-stabilized clay. *Geotech. & Geology Engneering*, 23(3). 309-319.

Rashid, Z. A., Alias, A. B., Aris, M. J., El-Harbawi, M., Rahman, N., & Som, A. (2010). Hazardous waste management: current status and future strategies in Malaysia. *International Journal of Environmental Engineering*, 2(1). 139-158.

Reinert, E. T., Brandenberg, S. J. and Stewart, J. P. (2013). *Measurements of Translational and Rotational Dynamic Stiffness for a Model Levee on Peat*. 10th International Conference on Urban Earthquake Engineering, Tokyo, Japan.

Robert, H. K. and Rober, L. K. (1996). *Treatment wetlands*. Lewis Publishers, Boca Raton, New York.

Rotta, G.V., Consoli,N. C., Prietto, P.D.M., Coop, M. R. and Graham, J. (2003). *Isotropic yielding in an artificially cemented soil cured under stress*. Geotechnique, 53(5). 493-501.

Saeed, K.A., Kassim, K. A. and Eisazadeh, A. (2012). Inferences of Cement based-solidification/ stabilization and heavy metals: A review. *Electronic Journal of Geotechnical Engineering*. 2555-2565.

Saitoh, S., Suzuki, Y. and Shirai, K. (1985). Hardening of soil improvement by deep mixing method. *Electronic Journal of Geotech and Environment.*

Samsuri., A. 1997. The application of palm oil fly ash in improving a petroleum well cement characteristics. *In: Proc. Regional symposium on chemical engineering*. 13–15 Oct. Johor Baru, Malaysia, Session B1-5, 332.

Santamarina, J.C., Klein, K. A., Wang, Y. H. and Prencke, E. (2002). Specific surface area: determination and relevance, *Canadian Geotech. Journal*, 39: 233-241.

Sariosseiri, F., Muhunthan, B. (2009). Effect of cement treatment on geotechnical properties of some Washington State soils. *Engineering Geology* 104, 119–125.

Seed, H. B. and Idriss, I. M. (1970). *Soil Moduli and damping factors for dynamic response analysis*. Report No. EERC 70-10, University of California, Berkeley. In Earthquake Engineering, Tenth World Conference, Balkerna, Rotterdam. By Sukhmander, S. (1992). *Dynamic strength and stability of refuse landfills during earthquakes*. 1205- 1216.

Seng, S. and Tanaka, H. (2012). Properties of very soft clays: A study of thixotropic hardening and behavior under low consolidation pressure. *Soils and Foundations* Vol. 52(2). 335–345.

Sha'abani,M. and Kalantari, B. (2012). Mass Stabilization Technique for Peat Soil – A Review , *ARPN Journal of Science and Technology.*

Sheng, C. and Li, Y. (2008). Experimental study of ash formation during pulverized coal combustion in O 2 /CO 2 mixtures. *Fuel.* Vol. 87. 1297–1305.

Sinsiri, T., Jaturapitakkul, C. & Chindaprasirt, P. (2006*). Influence of Fly Ash Fineness on Calcium Hydroxide in Blended Cement Paste,* Proceedings of Technology and Innovation for Sustainable Development Conference (TISD2006), Khon Kaen University, Thailand.

Soanes, C.and Stevenson, A. (2008). Concise Oxford Dictionary. Oxford University Press, USA.

Sobhan, K. and Mashnad, M. 2002. Tensile Strength and Toughness of Soil-Cement-Fly-Ash Composit Reinforced with Recyled high-Density Polyethylene Strips. *J. Materials in Civil Eng*., ASCE, 14 (2), 177-184.

Som P. Pichan, S.P. and O'Kelly, B. C. (2013). Effect of decomposition on physical properties of fibrous peat. *Environmental Geotechnics* Volume 1 Issue EG1.

Sposito, G. (2008). The chemistry of soils. 2nd Ed. Oxford university press Inc.

Stark, J. (2011). Recent advances in the field of cement hydration and microstructure analysis. *Cement and Concrete Research 41*. 666–678.

Stuart, B. H. (2004). *Infrared Spectroscopy: Fundamentals and Applications*. John Wiley & Sons. 224.

Stutzman, P. (2004). *Scanning electron microscopy imaging of hydraulic cement microstructure*. Cement & Concrete Composites 26. 957–966.

Sukumar, B., Nagamani, K., and Raghavan, S.R. 2008. Evaluation of strength at early ages of self-compacting concrete with high volume fly ash. *Construction and Building Materials*. 22. 1394–1401.

Tan, V.C.K. (2009). *Sustainable construction on soft soils in Sibu: A practical perspective*. Engineering Seminar on Peat, Sibu, Sarawak.

Tang, B. L., Bakar, I. and Chan, C. M. (2011). Reutilization of Organic and Peat Soils by Deep Cement Mixing. *International Journal of Environmental, Earth Science and Engineering* Vol:5 No:2.

Taylor, H. F. W. and Telford, T. (1997). *Cement chemistry*. 2nd edition. 459.

Terzaghi, K., R.B. Peck and G. Mesri (1996). *Soil mechanics in engineering practice*. 3rd ed., John Wiley and Sons, New York. ISBN Number: 978-0-471-08658-1.

Timoney, M. J., McCabe, B. A. and Bell, A. L. (2011). Experiences of dry soil mixing in highly organic soils. Ground Improvement Volume 165 Issue GI1.

Tolstoy, V. P., Chernyshova, L. V. and Skryshevsky, V. A. (2003). *Handbook of infrared spectroscopy.* Vol. 126, N 47. 15633–15634.

Trausch-Giudici, J. L. (2005). *Stress-strain Characterisation of Seebodenlehm*. Swiss Federal Institut of Technology Zurich.

Tremblay, H ., J. Duchesne, J. Locat and S. Leroueil (2002). Influence of the nature of organic compounds on fine soil stabilization with cement. *Canadian Geotech. Journal*, 39(3). 535-546.

Tsakiridis, P. E., Papadimitriou, G.D., Tsivilis, S. and Koroneos , C. (2008). Utilization of steel slag for Portland cement clinker production. *Journal of Hazardous Materials. Vol. 152, Issue 2*. 805–811.

Venmans, A. (2009), Summary Material Properties, AES1630 *Engineering properties of soil and rock*, Deltares: Delft.

Verwaal, W. (2004). Soil mechanics laboratory manual. Geotechnical laboratory of DGM, Thimpu, Bhutan.

Von Post, L. and Granlund, E. (1926). *Södra Sveiges torvtillgangångar I. Peat resources in southern Sweden*. Sveriges geoliska undersökning.

Wair, B. R. and DeJong, J. T (2012). *Guidelines for Estimation of Shear Wave Velocity Profiles.* PEER Vol. 08.

Wang, K.S., Lin, K.L., Lee, T.Y. & Tzeng, B.Y. (2004). The Hydration Characteristics When C_2S Is Present in MSWI Fly Ash Slag. *Cement and Concrete Research,* Vol.26, 323-330.

Wang, Y. H., Lo, K. F., Yan, W. M and Dong, X. B. (2007). Measurement Biases in the Bender Element Test. *Journal of Geotechnical and Geoenvironmental Engineering*. 2007.133:564-574.

Wong, L. S., Hashim, R. and Ali, F. (2013). Improved strength and reduced permeability of stabilized peat: Focus on application of kaolin as a pozzolanic additive. *Journal of Construction and Building Materials 40*. 783–792.

Wong, L. S., Hashim, R. and Ali, F. (2008) Engineering Behaviour of Stabilized Peat Soil. *European Journal of Scientific Research* Vol.21 No.4. 581-591.

Wong, L. S., Hashim, R. and Ali, F. (2008). Compression Rates of Untreated and Stabilized Peat Soils**.** *Electronic Journal of geotechnic and Engineering*. Vol. 13, Bund. F. 1-13.

Wong, L. S., Hashim, R. and Ali, F. (2009). Unconfined Compressive Strength of Cemented Peat . *Australian Journal of Basic and Applied Sciences,* 3(4): 3850-3856.

Wong, L. S., Hashim, R. and Ali, F. (2013). Utilization of sodium bentonite to maximize the filler and pozzolanic effects of stabilized peat. *Engineering Geology* 152. 56–66.

Wong, L. S., Hashim, R. and Ali, F. H. (2008). Strength and permeability of stabilized peat soil. *Journal of Applied Sciences*. 1-5.

Wong, L.S. (2010). *Stabilization of peat by chemical binders and siliceous sand*. PhD thesis, University of Malaya, Kuala Lumpur, Malaysia.

Xiao, L. and Li, Z. (2009). New Understanding of Cement Hydration Mechanism through Electrical Resistivity Measurement and Microstructure Investigations. *Journal of Materials in Civil Engineering*. Vol. 21. 368-373.

Yamashita, S., Fujiwara, T., Kawaguchi, T., Mikami, T., Nakata, Y. and Shibuya, S. (2007) *International Parallel Test on the Measurement of Gmax using Bender Elements* organized by TC-29. ISSMGE TC 29 Laboratory Stress Strain Strength Testing of Geomaterials, TC29-JGS.

Zainorabidin, A. and Bakar, I. (2003). *Engineering properties of in-situ and modified hemic peat soil in Western Johor*. In Proceedings of 2nd International

Conference on Advances in Soft Soil Engineering and Technology, Malaysia. 173-182.

Zeng, X. and Ni, B. (1998). Application of Bender Elements in Measuring G max of Sand Under K_o Condition. *Geotechnical Testing Journal*, ASTM, Vol. 21, No. 3. 251-263.

Zeng, X. and Ni, B. (1999). Stress-Induced Anisotropic G max of Sands and Its Measurements, ASCE *Journal of Geotechnical and Geoenvironmental Engineering*, Vol. 125, No. 9. 741- 749.

Zeng, X., (2005) *Cone penetrometer equipped with piezoelectric sensors for measurement of soil stiffness in highway pavement*. Ohio Department of Transportation Office of Research and Development. 1-70.

Zeng, X., Figueroa, J.L. and Fu, L. (2003). *Measurement of Base and Subgrade Layer Stiffness During and After Construction Using a Cone Penetrometer Equipped with Piezoelectric Sensors.* Proceedings of the International Conference on Highway Pavement Data, Analysis and Mechanistic Design Applications. Volume 2. September, Columbus, Ohio.

Zeng, X., Figueroa, J.L. and L. Fu. (2004) Measurement of Base and Subgrade Layer Stiffness Using Bender Element Technique. *Recent Advances in Materials Characterization and Modeling of Pavement Systems*. Special Publication 123. 35-45.

Zhu, W., Zhang, C. L. and Chiu, A. C. F. (2007). Soil–Water Transfer Mechanism for Solidified Dredged Materials *Journal of Geotechnical and Geoenvironmental Engineering*. 588-598.